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TREE GROWTH AND WATER USE RESPONSE TO THINNING IN A 47-YEAR-OLD LODGEPOLE PINE STAND

by

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ABSTRACT

Results from a 5-year lodgepole pine levels-of-growing-stock study showed trees grew more rapidly in diameter but less rapidly in height after a first thinning at age 47. During this period, there was no substantial transfer of growth from the cut trees to the better remaining individuals. Soil moisture withdrawal was substantially reduced at lower stand densities. This unused soil moisture is potentially available for increased streamflow. Some of the site potential released by thinning may also show up as understory forage.

Keywords: Stand density, thinning (trees), soil moisture, lodgepole pine, tree diameter measurement, tree increment measurement.

INTRODUCTION

Gross wastage of valuable productive capacity occurs where overly dense stands produce large volumes of wood on many small trees that cannot reach usable size. When reduction in number of stems can increase growth rate of the remaining individuals, wood production on usable size trees increases, provided the thinning is not too drastic. Furthermore, during the first years after thinning before the reduced number of trees can fully occupy the site, the unused productive capacity will probably show up as increased water production, or as greater understory growth that may have forage value for grazing animals.

A series of levels-of-growing-stock and spacing studies have been installed in eastern and central Oregon lodgepole pine stands. These are designed to quantify relationships between stand density and wood, water, and forage production. First 5-year results from the Snow Creek levels-of-growing-stock study established in a 47-year-old stand are presented in this paper.

STUDY, SITE, AND METHODS

The study is located on the Deschutes National Forest about 50 miles southwest of Bend, Oregon.

Site is about average for central Oregon, 52 feet at index age 50 years.[1/]

Vegetation is similar to the lodgepole pine/bitterbrush community described by Youngberg and Dahms (1970). Plants found included antelope bitterbrush (*Purshia tridentata*), wax currant (*Ribes cereum*), western needlegrass (*Stipa occidentalis*), bottlebrush squirreltail (*Sitanion hystrix*), Ross's sedge (*Carex rossii*), strawberry (*Fragaria virginiana*), and western yarrow (*Achillea lanulosa*).[2/]

The soil is a well-mixed pumice about 27 inches thick over a sandy loam mixed with gravel and cobbles that appear to be glacial outwash. The pumice contains well-rounded non-pumiceous pebbles mixed through the entire profile. Water table is high during the spring snowmelt period and on through much of June.

The stand was fairly dense prior to thinning. Crown competition factor values ranged from a low of 144 on one plot to a high of 219 on another (table 1). The prethinning range in basal area was from 110 to 140 square feet per acre. Crowns on most trees were short and narrow.

The experiment consists of ten 1/5-acre plots individually surrounded by a 1/2-chain buffer strip. Each of five levels-of-growing-stock treatments was randomly assigned to two plots per level. The first thinning was in the fall of 1962; the next thinning was at the end of 5 years, in 1967. Later thinnings are planned at 10-year or longer intervals.

1/ Site index based on height of the tallest tree per one-fifth acre at index age 50 years as read from curves in Dahms (1964).

2/ Plant names as listed in Hitchcock et al. (1955-69).

Table 1.--*Stand statistics per acre before thinning and for material removed by thinning*

Growing stock level and plot	Number of stems	Average d.b.h.[1]	Basal area	Bole area	Volume[2]	Crown competition factor	Site index
		Inches	*---Square feet---*		*Cubic feet*		
1 (lowest):							
3	1,325	4.1	135.0	30,374	2,475	206	50
9	1,830	3.3	125.3	27,932	2,210	219	45
Average	1,578	3.6	130.2	29,153	2,342	212	47
2:							
1	665	5.2	110.2	19,624	1,933	144	55
7	1,430	3.9	140.2	31,911	2,667	214	50
Average	1,048	4.6	125.2	25,768	2,300	179	53
3:							
8	868	4.9	128.8	25,953	2,425	173	54
10	1,900	3.1	118.3	24,416	2,109	214	49
Average	1,384	4.0	123.6	25,184	2,267	194	51
4:							
4	1,185	4.0	121.8	25,938	2,239	182	52
5	1,645	3.5	132.7	29,575	2,444	217	49
Average	1,415	3.8	127.2	27,756	2,342	200	51
5 (highest):							
2	1,250	4.1	130.2	25,528	2,431	194	52
6	920	4.4	112.0	23,510	2,075	159	58
Average	1,085	4.2	121.1	24,519	2,253	176	55
Average, all plots	1,302	4.0	125.5	26,476	2,301	192	51.5
Portion of stand removed by thinning:							
1	1,456	--	105.2	--	1,864	--	--
2	753	--	77.3	--	1,381	--	--
3	884	--	43.5	--	768	--	--
4	665	--	22.1	--	374	--	--
5	250	--	4.1	--	16	--	--

[1] Arithmetic mean.

[2] Total under bark volume of the entire stem from the ground line to the tip.

The levels-of-growing-stock treatments were defined in terms of bole area, first described by Lexen (1943). Bole area is a close approximation of main stem cambium area. Levels chosen at the time of the first thinning were 5,000, 10,000, 15,000, 20,000, and 25,000 square feet of bole area per acre. In terms of basal area, this amounted to 25, 48, 80, 105, and 117 square feet per acre, respectively (table 2). Trees removed were those diseased and less vigorous.

Diameter and height of all trees were measured in the spring of 1963 and again in the fall of 1967. Upper bole diameter measurements on a sample of trees were taken in both 1963 and 1967 to provide a basis for calculating volume and bole area equations at each date.

Soil moisture was measured with a nuclear probe.[3/] Measurements were made to estimate soil moisture use in the year before thinning and in each year thereafter during the first 5-year postthinning period.

RESULTS

DIAMETER

Average diameter growth of all trees increased steadily with each decrease in stand density from the highest level to the lowest (fig. 1).

[3/] Three mechanically spaced tubes were used as soil moisture sampling points on each plot. An attempt was made to insert 5-foot tubes at each of these points. However, the very coarse, gravelly nature of the soil below 4 feet made installation of 5-foot tubes extremely difficult. Therefore, many tubes were only 4 feet long and results are reported for 4 feet of soil. Calibration curves developed by Barrett (1970) were used to convert the difference in counts per minute from spring to fall into water use.

Table 2.--*Stand statistics per acre after fall 1962 thinning and at end of 1967 growing season*

Level	Number of trees	Entire stand							Volume of 100 largest diameter trees[2/]
		Average spacing	Average d.b.h.[1/]	Average height	Basal area	Bole area	Crown competition factor	Volume[2/]	
		Feet	*Inches*	*Feet*	*---Square feet---*			*--------Cubic feet--------*	
Beginning of 1963 growing season:									
1 (lowest)	122	18.9	6.1	41.0	25.0	4,842	31	478	428
2	295	12.2	5.4	38.8	47.9	9,936	64	919	496
3	500	9.3	5.4	37.0	80.1	15,841	106	1,499	585
4	750	7.6	4.8	35.6	104.1	22,118	145	1,968	602
5 (highest)	835	7.2	4.8	35.6	117.0	24,814	161	2,237	663
End of 1967 growing season:									
1 (lowest)	122	18.9	6.6	43.6	29.4	5,740	35	606	540
2	295	12.2	5.8	41.6	56.3	11,992	71	1,174	637
3	500	9.3	5.7	40.2	88.5	17,978	114	1,698	664
4	732	7.7	5.1	38.9	113.1	25,124	151	2,285	719
5 (highest)	792	7.4	5.0	38.6	119.0	26,424	163	2,387	753

[1/] Arithmetic mean.
[2/] Total under bark volume of the entire stem from the ground line to the tip.

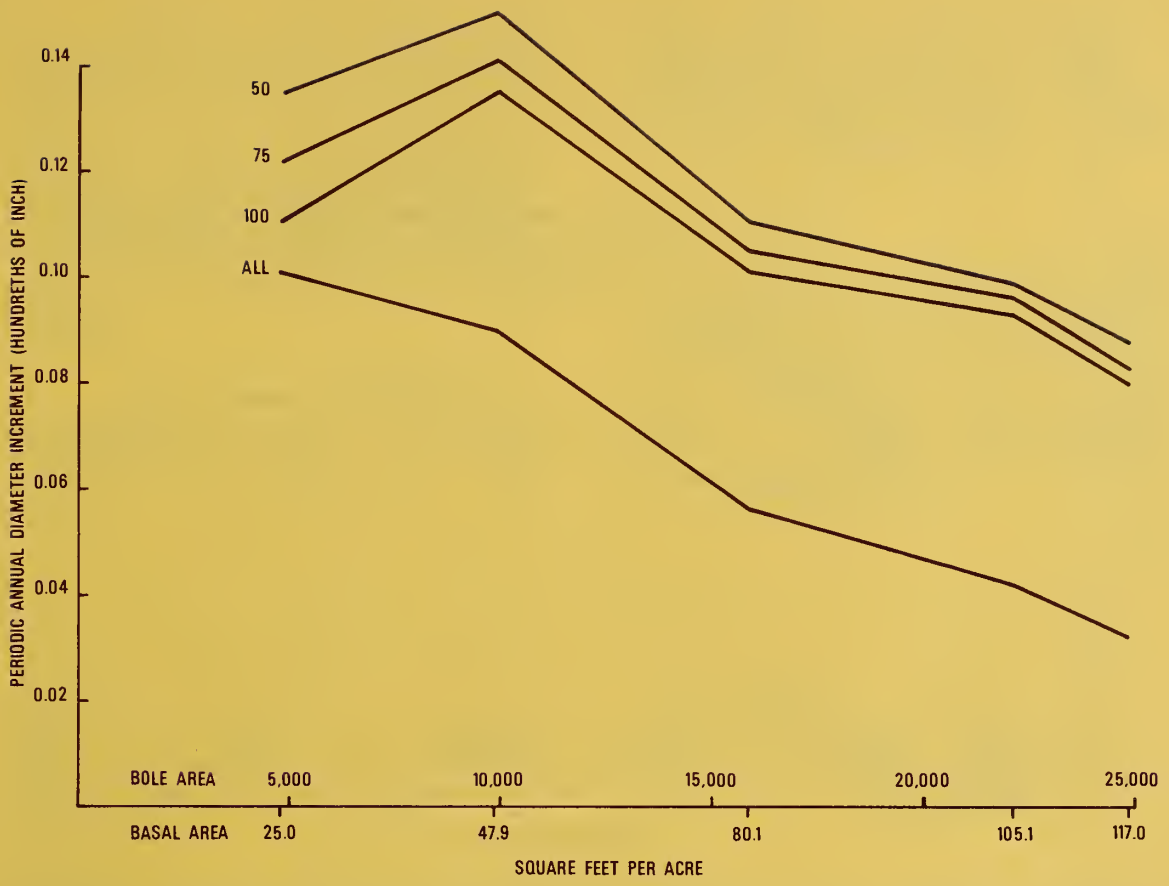

Figure 1.--Periodic annual diameter growth of the 50, 75, and 100 largest diameter trees per acre and all trees.

This linear relationship between stand density and diameter growth was highly significant in a statistical sense.

The same general trend of more rapid diameter increase with decreasing stand density also held for the 50, 75, and 100 largest diameter trees per acre except that the increase at the lowest density was less than that at the next-to-lowest density (fig. 1). Although this difference between levels 1 and 2 was not significant at the 5-percent level, the drastic reduction in height growth suffered by the most widely spaced trees (see fig. 2) suggests that the diameter growth decline of the largest trees at the lowest density may be a real effect of density.

There was also a tendency for larger trees to grow more rapidly in diameter than smaller ones. At all treatment levels, the 100 largest trees grew more rapidly than all trees, and the 50 largest trees grew faster than the 100 largest.

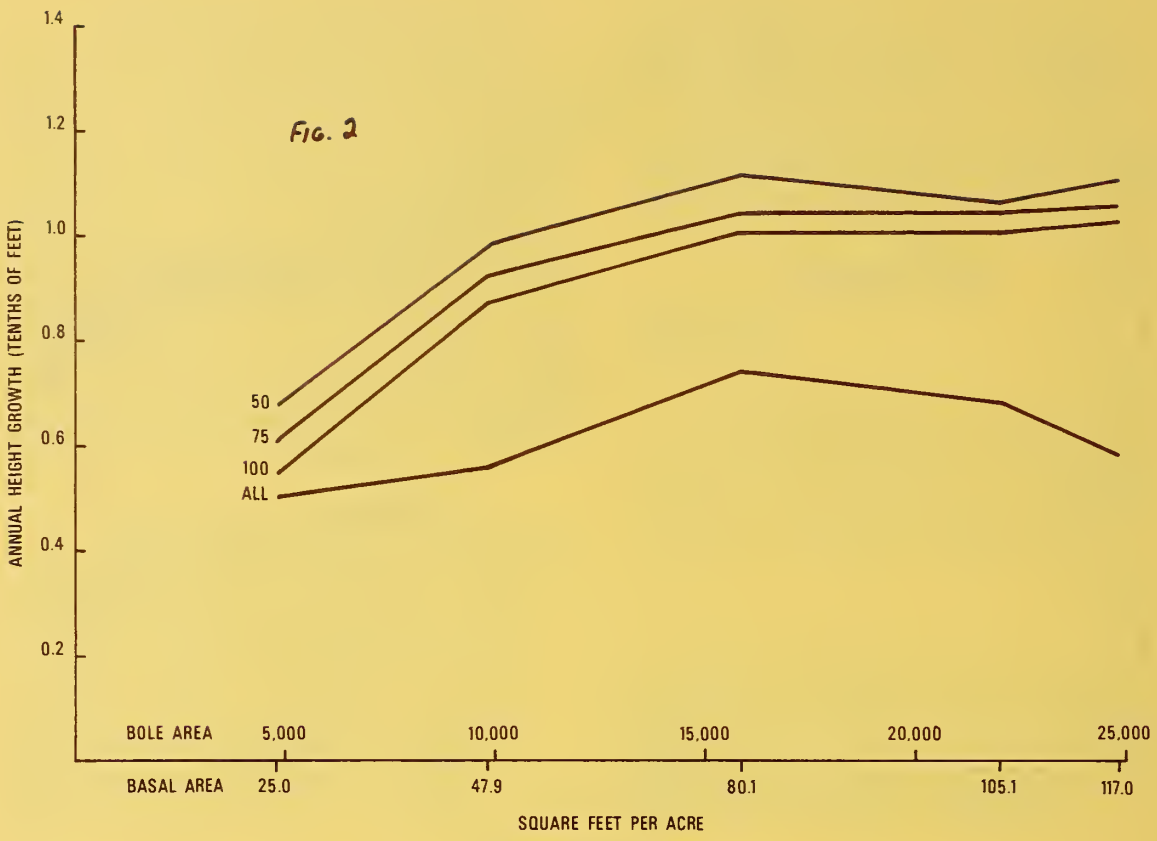

Figure 2.--Annual height growth of the 50, 75, and 100 largest diameter trees per acre and all trees, on an average-per-tree basis.

Linear regressions of periodic annual diameter increment on initial diameter were statistically significant on seven of the 10 plots. Regressions were nonsignificant on one plot at each of the three lower density levels. Regression on the plot where fit was best accounted for only 32 percent of total variation, but most did not do nearly that well. Thus, growth predictive value of initial diameter was not high.

HEIGHT

Height growth of the larger trees was definitely retarded by thinning. The 50, 75, and 100 largest diameter trees per acre were most affected at the lower two density levels (fig. 2). Statistical tests showed that a second-degree curve made a significant improvement over a linear regression for expressing the relationship of height growth of the larger trees as a function of stand density.

Height growth of the larger diameter trees was greater than that of the smaller trees. On every plot, the 100 largest trees grew more rapidly than all trees. Similarly, the 75 largest trees grew more rapidly than the 100 largest, and the 50 largest trees grew more rapidly than the 75 largest on all plots.

There was no difference in average height growth of all trees associated with stand density. The larger number of small, slowly growing trees present at the higher densities cancelled the greater height growth of the larger trees.

BASAL AREA

Basal area increment increased sharply as stand density increased from the lowest level to the next highest one (fig. 3). However, beyond the second level there was little relationship between gross basal area increment and

Figure 3.--Relationship between periodic annual basal area increment and stand density after thinning.

stand density. A regression of gross basal area increment on logarithm of basal area proved to be highly significant,[4] mainly because of the low increment at the lowest density.

Mortality accounted for 74 percent of gross basal area increment at the highest density level but only 12 percent at the next lower level. No mortality occurred at the three lower levels (table 3).

CUBIC VOLUME

Gross cubic volume increment increased irregularly as stand density increased (fig. 4). Despite large deviations from the general trend, a linear regression of volume increment on bole area accounted for 40 percent of the total variation and was statistically significant.

The erratic progress of increasing volume increment with increasing stand density resulted from rather large differences between plots treated alike. For example, at the middle density level, one plot produced 54.6 cubic feet but the other, only 24.7. Plot 10, the low producer, had the greatest number of stems of any plot in the experiment before thinning (table 1). A probable reason for the poor performance is that trees on this plot were too suppressed to respond well, but it is also possible that site quality is lower. Similar results were experienced with another levels-of-growing-stock study at Twin Lakes in Oregon, but during the second 5-year period, the large differences between plots treated alike had mostly disappeared (Dahms 1971).

Mortality accounted for 41.5 percent of the gross volume increment at the highest density and 6.5 percent at the next highest density. No mortality occurred at the three lower densities.

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[4] Orthogonal comparisons in regression showed that a second-degree curve would account for 81 percent of the total variation in basal area increment contrasted with 58 percent for the logarithmic expression. However, the logarithmic equation has long been used for estimating basal area increment and logically fits the situation.

Table 3.--*Periodic annual growth and mortality of lodgepole pine per acre after initial thinning at age 47*

Growing stock level	Entire stand												Volume increase of 100 largest diameter trees[1]
	Basal area			Bole area			Crown competition factor			Volume			
	Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross	
	Square feet			*Square feet*						*Cubic feet*			
1 (lowest)	0.897	0	0.897	179	0	179	0.8	0	0.8	25.5	0	25.5	22.4
2	1.674	0	1.674	411	0	411	1.4	0	1.4	51.0	0	51.0	28.3
3	1.678	0	1.678	427	0	427	1.6	0	1.6	39.6	0	39.6	15.8
4	1.610	.222	1.832	601	76	677	1.2	0	1.2	63.4	4.4	67.8	23.3
5 (highest)	.404	1.148	1.552	322	241	563	.4	0.4	.8	30.0	21.3	51.3	17.9

[1] Volume increase of 100 largest trees per acre is the difference in volume between those that were largest at the beginning of the period and those that were largest at the end.

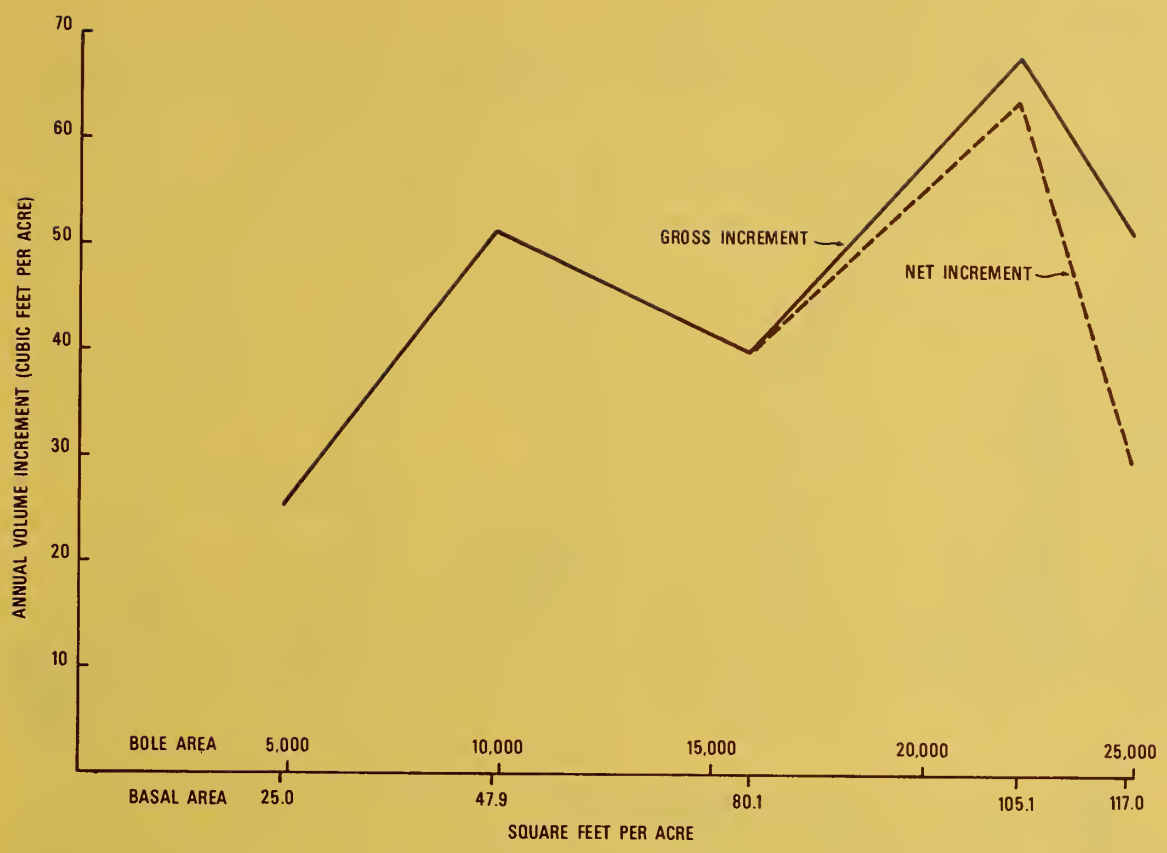

Figure 4.--Relationship between periodic annual volume increment and stand density after thinning.

Differences between treatments in volume added to largest trees did not logically relate to stand density and could easily be accounted for by random variation (table 3). Greater diameter growth at the lowest stand density was approximately offset by lesser height growth.

SOIL MOISTURE

Soil moisture withdrawal was definitely less after thinning than before on the two plots given the lowest stand density treatment. Additional water left in the top 4 feet of soil after thinning compared with prethinning ranged from 3.3 inches in 1967 to 7.2 inches in 1965 and averaged 5.0 inches for the 5-year period at the lowest stand density level (fig. 5). At the highest stand density, the range was from a 0.6-inch greater use in 1967 to a 2.6-inch lesser use in 1965, with an average lesser use of 0.6 of an inch. Water saving by the heavy thinning, or the difference between the high density and the low

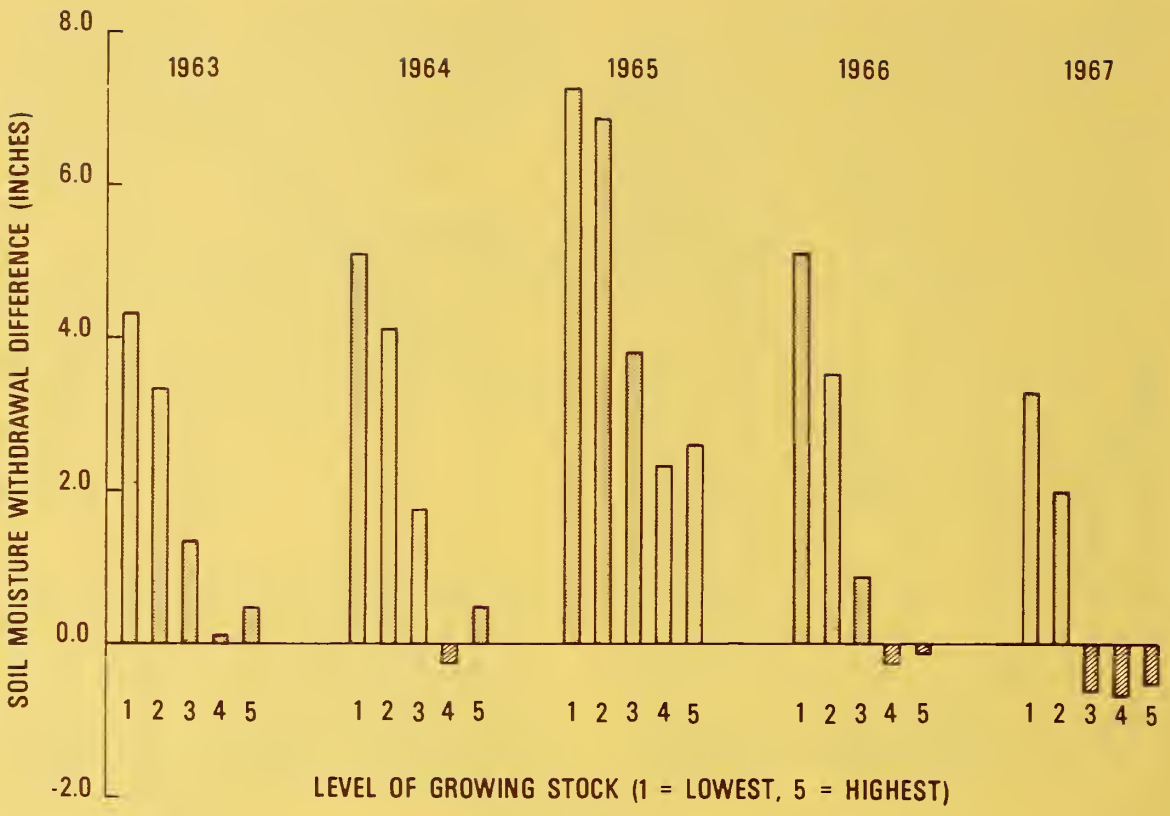

Figure 5.--Difference between prethinning (1962) and postthinning (1963-67) soil moisture withdrawal, by year and level-of-growing stock. (Difference is water use in postthinning years subtracted from prethinning use. Greater postthinning use in a few instances resulted in negative differences.)

density treatment, averaged 4.4 inches over the 5-year period.

There was no evidence to suggest that water use on the lowest density plots might be increasing relative to that on the higher density ones as the years since thinning passed. Failure of the year-treatment interaction during the 5 postthinning years even to approach statistical significance confirms the visual impression obtained from figure 5. These results are not the same as those from a similar study in a younger stand growing near Twin Lakes. There, soil moisture use increased at the lower densities relative to that at the higher levels during the first 5-year period (Dahms 1967).

Volume increment was closely related to amount of soil moisture withdrawn. A regression of gross volume increment on average annual soil moisture withdrawal over the 5 postthinning years accounted for 60 percent of the total variation in volume increment and proved to be statistically significant at the 1-percent level. This result is comparable to that obtained at Twin Lakes (Dahms 1967).

DISCUSSION

Delaying thinning until the Snow Creek stand was 47 years old caused a substantial waste of site productivity. A large volume of wood was grown on trees that had almost no chance to reach usable size. As an example, if we assume 208 trees (halfway between levels 1 and 2) will be able to reach usable size before another thinning is needed, about 70 percent of the standing volume in 1962 was in excess trees too small to use.[5/]

Tree growth response to thinning was not large during the first 5 years. At level 2 (10,000 square feet of bole area per acre), diameter growth of the 100 largest trees per acre was 169 percent of that at the highest density level. However, height growth was only 85 percent of that at the highest level. At the lowest density level, diameter growth was only 140 percent of that at the highest level and height growth, 54 percent (figs. 1 and 2).

Insight into probable volume increment relationships is provided by soil moisture use patterns. If year-to-year trends of volume increment on low density plots relative to high density ones follow the pattern for soil moisture use, there is no tendency for volume increment at low densities to approach that at higher densities as time passes. Also, the very low volume increment on plot 10 coupled with the low soil moisture use both before and after thinning further suggests that this plot is of lower site quality or that stagnation may have set in.

Will trees as old as 47 years recover from the shock of a heavy thinning and resume normal height growth? Staebler's (1956) experience with shock (height growth suppression) in Douglas-fir and the subsequent resumption of a normal growth rate suggests that Snow Creek trees, too, can be expected to resume normal height growth.[6/] The fact that Alexander et al. (1967) found no evidence of reduced height growth in natural stands of very low densities provides additional basis for hope.

Crown size reduced by density may always limit diameter growth to something less than what would

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5/ The 70-percent figure was obtained by averaging volumes cut from the two lowest levels as shown in table 1 and expressing the average as a percentage of the average prethinning volume of these levels.

6/ Resumption of normal growth on Staebler's trees after 6 to 8 years was confirmed by personal communication with Richard E. Miller, Pacific Northwest Forest and Range Experiment Station, Olympia, Wash.

have been possible with an earlier thinning (fig. 6). It does not seem possible that photosynthetic surface per unit of cambium area can ever be as great on these once-suppressed trees as on trees that have always had adequate growing space. Although this study has not produced solid evidence that thinning in lodgepole pine stands as old as 47 years will increase usable wood production, there are some grounds for optimism.

Probable water yield increases may be one of the biggest incentives for thinning an older lodgepole pine stand such as the one at Snow Creek. The much reduced evapotranspiration drain on soil moisture from the lower densities can reasonably be expected to show up as increased streamflow. As Herring (1968) points out, there are some if's in translating soil moisture savings into increased water runoff. However, Packer and Laycock (1969) maintain that reductions in density of vegetation almost always produce increased streamflow. Consequently, it is reasonable to expect thinning to increase water production until roots and crowns of the reserve trees reoccupy the site or until understory shrubs and grasses expand into the new growing space. Barrett (1970)

Figure 6.--Left, a low density plot at Snow Creek thinned at age 47 years. Notice the short, narrow crowns. Right, a low density plot at Twin Lakes thinned to the lowest density at age 26 years. Notice the much longer and wider crowns.

demonstrated that understory shrubs and grasses could be as water-demanding as trees.

Thinning offers the potential of diverting sites from production of wood on unusable trees into production of forage for grazing animals. This result on somewhat similar studies has been reported by Barrett (1970) and McConnell and Smith (1970). Dealy of the Big-Game Habitat Project at LaGrande is studying this aspect of stand density control at Snow Creek.

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